Before the
Federal Communications Commission
Washington, D.C.

In the matter of:

Amendment of Part 73 to permit Permanent Licensing of AM Synchronous Booster Stations	)	**RM No. 11779**

COMMENTS OF KINTRONIC LABORATORIES, INC.

The domestic and international broadcast radio engineering, design, and manufacturing firm of Kintronic Laboratories, Inc. ("KTL") hereby submits these Comments in response to the Petition for Rulemaking, Amendment of Part 73 to permit Permanent Licensing of AM Synchronous Booster Stations, RM No. 11779, dated November 29, 2016. This proceeding logically follows from the Commission's recent actions on AM Revitalization, the 13-249 Notice of Proposed Rulemaking [NPRM] of October 31, 2013, and the succeeding First Report and Order, Notice of Proposed Rulemaking (FNPRM), and Notice of Inquiry (NOI), dated October 23, 2015. In those proceedings, the Commission solicited Comments on its various further specific proposals to revitalize AM radio and also invited submission of further proposals. Based on experience from the 65-year history of our firm and its founder, Louis A. King, MSEE, PE, providing engineering consulting and product services to the licensees of U.S. AM radio stations as well as many international broadcasters, we intend with these comments to provide focused analyses of the Commission's specific proposals related to AM transmission standards and also add to the discussion with further proposals we believe to be essential for AM revitalization. Our comments will focus on specific rule changes that can be used by AM stations in general to improve their flexibility in developing technical facilities to improve their coverage in the existing AM band, specifically in the utilization of modern AM synchronization techniques to achieve low-cost, low-artifact synchronous boosters for improving coverage in adjacent population zones without engendering additional interference to other stations. We believe that the Commission's previously stated goal of truly revitalizing the AM broadcasting service can only be achieved by a concerted, multi-faceted approach to this complex technical, economic, and policy challenge. Ultimately, the American listening public will be the real beneficiary of these changes.

One of the key technologies to support this wide-ranging AM Revitalization effort is the broad application of modern frequency and phase synchronization to AM transmissions, both in proximal areas (as specifically addressed in the current proceeding), and in the wide-area synchronization of co-channel carrier frequencies. Our firm has previously addressed these issues in Reply Comments in both 13-249 proceedings and in several related publications.

OVERVIEW. We have reviewed the present Petition for Rulemaking and view it as an essential component of the overall goals of the two earlier 13-249 AM Revitalization actions; we further wholeheartedly support the Commission's broad goal of revitalizing the AM radio service. AM radio constitutes the most bandwidth-efficient broadcast medium and provides an essential service to many Americans, particularly in rural and remote areas, and those traveling in the vast expanses of this nation. We strongly concur with the full Commission's efforts in this regard, especially Commissioner Pai's efforts to champion this thrust, and with Commissioner Clyburn's recognition that AM provides a unique venue to facilitate female and minority media management and ownership, as well as to provide vital programming diversity for the American public, particularly in niche markets and demographics. AM radio, due to its generally lower capital requirements, can also provide a realistic setting for family-based, community-focused station programming and ownership, especially in smaller localities. AM radio is truly a national resource, a source of unique voices, and one that we can ill afford to abandon, particularly in light of its unique propagation characteristics and tremendous reach, especially in times of local, regional, and even national emergencies***. Truly, this action has the rare potential of conserving a unique national resource.***

Since the original NPRM over three years ago, we have as yet seen no substantive response from the Commission on the two salient issues we (and many others) have identified as key to the survival and ultimate viability of the AM band — **(1)** the worsening electromagnetic environment; and **(2)** the concurrent failure of the consumer-products industry to provide the listening public with high-quality AM receiver systems (comparable to their FM counterparts), particularly in the areas of sensitivity, selectivity, noise rejection, and audio bandwidth. As we cited then, these two effects are in fact closely interrelated, since the steadily increasing noise floor in the AM band has materially contributed to the unfortunate trend to reduce AM receiver bandwidths even further than those typical in the 1960s and '70s. It has been all too easy for the receiver manufacturers to simply reduce overall receiver bandwidths down to even 2-3 kHz (sometimes worse than telephone grade!) to address the pervasive issues of electromagnetic interference (EMI) noise from power lines, LED- and fluorescent-lamp ballasts, personal computers, consumer devices, battery chargers, and the like, not to mention broadband static impulses from lightning and increased adjacent-channel and alternate-channel interference from more recently allocated AM stations. Added on top of all this is the progressive trend in the automobile industry to replace metal body parts with plastic (which worsens EMI shielding), adapt windshield-type antennas (which provide markedly poorer reception performance for both AM and even FM), and add a multitude of noise-generating microcomputers for engine control, antiskid braking systems, and the like. The net result for the public has been AM radios with very low audio and reception quality.

It is therefore imperative to the long-term sustainability of AM radio that the Commission strongly encourage (or, via legislation, even mandate) significant improvement in consumer AM receiver systems. Without this, the American listening public will continue to regard AM as a noisy, low-fidelity medium and will consequently tune out. In the two 13-249 actions the Commission is, we believe, very wisely considering several major technical improvements to the AM stations' transmitting system and allocation requirements, ***but without advanced consumer-receiver features to address the severe noise, interference, and bandwidth challenges to good, clean AM-band reception, the appeal of AM to the public will inevitably be lost***.

In the time since the NPRM issuance, we have been informally apprised by staff that though the Commission would be willing to assist in certification of receivers for minimum performance standards, the agency could not consider mandating AM receiver performance without specific signed legislation passed through Congress. As a result, our company has engaged in two separate internal development projects to design advanced, high-performance DSP-based AM/FM receivers, one a professional instrument-grade unit, and the second (collaboratively with a partner firm) to produce a high-volume, low-cost software-based DSP high-performance consumer-type unit, initially in table-top format. The latter unit is due to be completed early next year. ***Both designs will offer AM receiver parity with the dominant FM band to enable the user to make listening choices on a much more level playing field***. The relevant technical receiver standards to achieve effective parity include: **(1)** low internal noise floor; **(2)** high overall RF sensitivity, selectivity, and dynamic range; **(3)** highly effective noise (EMI) rejection**; (4)** full 10-kHz audio bandwidth capability (adaptive) with low distortion; and **(5)** stereo capability [both AM and FM].

With these key AM reception issues as a continuing backdrop, we now move to the salient current issue of implementing both the technology and providing a permanent legal basis for AM transmitter synchronization, as we cited in our Reply Comments in both earlier 13-249 AM Revitalization proceedings.

<u>Proposal 1</u> – Immediately Open Local Synchronous Booster Stations to Permanent Licenses

We emphatically support the Petition of Eng. Wifredo G. Blanco-Pi [RM-11779] on the beneficial use of synchronous transmission by AM stations to provide coverage of isolated areas of significant population and improve service to the public, as he cited from his experience with multiple installations on the island of Puerto Rico. We also state our full agreement with Comments from duTreil, Lundin, & Rackley, Inc. (dLR), Hatfield & Dawson, Sellmeyer Engineering; Brian Henry; Cavell, Mertz & Assoc., Inc.; and others in the engineering community supporting the Petition by Eng. Blanco-Pi. <u>The requirement to continually re-authorize synchronous boosters is an unnecessary administrative burden for both the licensees and the Commission staff. The technology of local and wide-area synchronization of dispersed transmitters via GPS and similar means has been well-proven in numerous communications venues, including television, cell-phone base stations, and even in HD radio systems; thus, the technology is well-established and there is clearly no justification to continue its "experimental" designation. It is therefore incumbent on the Commission to provide permanent licensing for these facilities</u>. Details of the synchronous-booster operations on the two AM channels in Puerto Rico are documented in the 2015 NAB Engineering Conference paper we co-wrote with Eng. Blanco-Pi and his son Eng. Blanco-Galdo [8]. We fully agree with the Reply Comments on the subject of AM boosters in the original 13-249 NPRM from dLR, and further strongly endorse the new Rules they have suggested for regulating synchronous boosters. We recite these items below, with a few modifications based on our own separate studies:

(1) A synchronous AM system should be defined as a master, licensed standalone station with one or more synchronized, co-frequency, lower-power booster transmitters carrying identical modulation formats and time-synchronized audio signals. All boosters should be sited within the 2 mV/m daytime contour, or 40 miles of the master transmitter's location, whichever is greater.

(2) Synchronous operation should require absolutely synchronized carrier frequencies (also see Proposal 2 below). If precision offset operation is desired to minimize standing-wave fading zone effects between transmitters, this should be accomplished via cyclic or randomized phase-shift means in the carrier reference(s) of the booster unit(s). Additionally, precise time-matching of audio modulation and phase-matching of transmitted AM sidebands (including transmitters, matching networks, and antennas) at each synchronous site are required but precise implementation details should be left to the broadcaster's discretion, including with CQUAM and HD operations. We believe the frequency tolerance should be 0.01 Hz maximum, and preferably 0.001 Hz, which is readily achievable with typical GPS-based references.

(3) Synchronous systems should consist of multiple authorized transmitters with normally protected daytime signal-level contours that overlap or are contiguous with nighttime operation, even if higher nighttime interference levels might result in disjointed interference-free contours.

(4) Nighttime-only synchronous transmitters at locations meeting the daytime criteria should be authorized, if desired, so long as they comply with normal existing channel allocation Rules.

(5) Each transmitter in a synchronous system should be studied for allocations with each such transmitter considered individually. Total RSS interference to other stations from the composite system shall be within existing limits (including standard exclusions).

(6) A system of synchronous transmitters, each of which meets all applicable allocations criteria with regard to protecting other stations (except each other) from interference when considered alone, should be licensed without regard to extension of the coverage area of the primary station. If overall coverage is expanded without interference being produced to any other station, that is explicitly permitted.

(7) As synchronous boosters may have intentionally limited power and coverage areas, no explicit minimum antenna efficiency, height or ground system requirements should apply to them. This would permit low-profile, smaller, less-efficient antennas (such as the Kinstar) to minimize land-acquisition and construction costs, while providing normal daytime, critical-hours, and nighttime protection levels to other stations.

(8) A synchronous system of transmitters (i.e., a master station and its set of boosters) shall count as one station for the purposes of ownership rules, license renewal, and transfers.

The aforementioned synchronous-booster system could be of significant benefit to Class-C and -D stations with limited nighttime coverage, as well as other stations (mostly Class-B but also even some Class-A facilities) with deep nighttime directional-antenna nulls. All these stations could greatly benefit from the improved population coverage at night and during critical hours, particularly where urban/suburban sprawl has expanded beyond the stations' existing strong-signal zones. Unlike FM translators, such on-channel boosters would serve to increase the AM stations' audiences while concurrently maintaining the future viability of the band. The use of synchronous boosters could clearly provide new, effective nighttime AM signals into each community from the local area, at very low cost to the stations involved and with significant public benefit. Further, these and other such synchronous boosters could well prove to be an economic boon to many struggling AM operations by permitting tailored coverage areas to match listening locales, as well as providing enhanced signal levels to overcome localized noise sources, especially in urban and industrialized areas.

It is useful to examine how the phases/delays of the audio and RF components of the AM radio signals can affect reception quality in the field, particularly in signal-overlap regions. For instance, the RF signal delay is very roughly 1 millisecond for 186 miles (corresponding to the speed of light in air). At a point equidistant from two omnidirectional, co-phased (synchronous) transmitters with equal power and propagating via groundwave mode over land paths of identical RF conductivity, the two RF signals will arrive with equal amplitudes and delays (phases). Now if we assume that the RF carriers and the associated sideband signals are precisely in phase (matched in time) as they leave the two antennas, at the exact midpoint between the two transmitters the RF signals and the detected audio will also be in phase; the signals can be added algebraically to calculate the resultant. Now for points *not* equidistant from the two transmitters, the RF signal vectors will add; in general, there will be augmentations and cancellations of the two waves occurring at spatial intervals of one-half wavelength, essentially the same as is the case for standing waves on a mismatched transmission line. Modulation distortion will be minimal near the 0°-additive points and rise somewhat at quadrature-phase contours, and peak as the summed signal approaches null at the 180° points. Obviously, near the equal-signal points, the standing wave patterns will exhibit maximum variations; in fact, §73.182(t) of the Commission's Rules defines the region of "satisfactory service" for synchronous stations as areas where the ratio of field strengths is ≥ 6 dB (≥ 2:1). However, the Rules as quoted did not assume the accurate time-synchronization of both audio components and RF sidebands; as cited by Blanco-Pi and dLR, the audio time-matching significantly mitigates the apparent distortion and greatly reduces the area of discernible distortion. The interference patterning in the synchronous overlap zone can be further reduced by phase-dithering of the booster signal(s), either in a cyclic or random-phase fashion. Terrain variations, buildings, and other groundwave scatterers or diffractors (i.e., multipath sources) will also reduce the magnitude of these overlap-zone disturbances via the inherent dithering of carrier phase. In moving vehicles, the audible effects will be even less, especially on speech programming. It has been long known that the static distortion zones can be designed to fall over less-populated areas and major arteries; for instance, the overlap zones (near 1:1 signal ratios) would obviously be configured to fall in the more rural areas between cities. Further, U.S. Patent 7,881,416 describes the further reduction of these standing-wave patterns (and distortion) with the use of additional low-power localized boosters in or near the equal-signal zones. The net result of all this is that synchronized AM boosters are indeed ready for immediate wide-scale deployment. Once the basic synchronization of local AM booster transmitters is legally facilitated on a routine basis, the next logical step is to apply the same technology to geographically separated co-channel stations, as we have suggested in our earlier filings [1], [2]. We summarize these findings in the next paragraphs.

Proposal 2 – Mandate Regional/National Synchronization of All AM Stations

Three papers, published by the IEEE and NAB in the 2007-2010 time frame, [3], [4], [5], four U.S. Patents [6], and a paper at NAB 2015 [8], described a straightforward but highly accurate carrier-frequency synchronization scheme for actively, automatically locking multiple, remotely located AM broadcast transmitters to a common frequency/timing reference source such as GPS. The extremely tight frequency lock (to ~1 part in 10^9 or better) permits the effective elimination of audible and even sub-audible beats between the local (desired) station's carrier signal and the distant stations' carriers. Generally, an AM radio listener during the evening and nighttime hours, and to a lesser extent in the early morning, receives undesired skywave signals from several distant co-channel stations as well as the desired local (groundwave) signal. These carrier-beat components in the current (non-synchronized) scenario can cause annoying modulations of the desired station's audio at the receiver and concurrent distortion of the audio modulation from the distant station(s) and often cause listeners to "tune out" due to the poor reception quality. This is quite understandable since the average carrier power is on the order of 10 dB above that of the typical levels of the sideband modulation components, and the inter-carrier beats will dominate the receiver's AGC and thus modulate the audio level. Along with EMI, these beat-related effects are certainly ***a*** (if not ***the***) principal factor in the degradation of evening and nighttime AM fringe-area reception quality and the resulting loss of outlying listeners for virtually *all* AM stations. Perhaps the most deleterious aspect of these beats is the listener-annoyance factor, in that the high-level artifacts (volume modulation, cyclic distortion, and pronounced swishing sounds) often quickly induce listener tune-outs. This situation is not only progressively worse further into the fringe areas of the desired stations (usually in the outer suburbs of the city of license), but also occurs much closer in, in the deep nighttime nulls of directional stations. The current poor state of repair of many AM directional arrays, plus the low-power pre-sunrise/post-sunset (PSRA/PSSA) operations at many Class-D stations, only exacerbates these problems.

If, however, we employ carrier synchronization, all of these signals' frequencies can be held to within about 0.01-0.001 Hz of each other, and any resulting carrier beats will be of such long periods that the beats will be effectively suppressed by the action of the receiver's AGC circuitry and become completely unnoticeable to the listener. The significant reduction or elimination of the beats and related effects achievable via synchronization will greatly enlarge the effective *co-channel interference-limited* listening area of the desired station (from 4 to 10 times as indicated in our extensive laboratory and limited field tests, dependent on program material) and simultaneously reduce the corresponding interference of the local transmitter to the distant stations as well. In addition, AM stereo (CQUAM) reception will be particularly improved by minimizing the phase shifts induced by co-channel interfering signals; HD signals will also benefit via reduction in beats from co-channel analog signals.

The automatic frequency-control hardware described in the references is inexpensive, requires no periodic recalibration, has essentially zero long-term drift, and could employ alternate wide-area frequency references of suitable accuracy, including broadcasts from WWVB, LORAN-C, and equivalent sources. The basic configuration of a commercially available GPS-disciplined oscillator which solves this problem is extremely simple and costs under $300 (including the GPS antenna). [Newer units, responding to the increased volume in frequency/time synchronization markets, are even less expensive (e.g., < $150)]. The main oscillator is a conventional high-stability ovenized quartz-crystal type. To counter long-term drifts, the oscillator is automatically adjusted to track a high-precision source of standard frequency obtained from a specialized GPS receiver (or other source), usually at 10.000 MHz. This very stable local reference frequency is then used as a clock for a standard digitally implemented frequency synthesizer, which is programmed to generate the specific (AM broadcast) transmitter carrier frequency desired. The stability of the disciplining source, typically ~ 1 part in 10^9 to 10^{11}, is thus transferred to the final AM transmitter carrier output frequency. Most modern, synthesizer-based transmitters can directly lock to the precision disciplined 10-MHz source, while older units usually require external references at either 1×, 2×, or 4× the final frequency. In these latter cases, the existing transmitter crystal can usually be satisfactorily "pulled" via injection locking.

The effectiveness of the synchronization concept to reduce interference effects was demonstrated by ORNL researchers in extended documented measurements using a laboratory test setup, as described in the references above, and confirmed by field measurements in 2015 [8]. Many hours of careful subjective listening were conducted, with the two interfering units both precisely on-frequency with the main unit (synchronous operation) and with the two interferers at various frequency offsets, from below 1 Hz to above 10 Hz. The most audibly annoying beats were generally judged to be below roughly 2 Hz, so several tests were conducted with offsets of 0.7 and 1.7 Hz, respectively, which tend to more closely emulate current typical AM channel beat characteristics. Subjective measurements to determine the familiar audible interference assessment criteria of "imperceptible", "perceptible", "annoying", and "objectionable" were made and documented. Overall, the net effect to the listener of synchronizing the AM carriers and thereby eliminating the beats is on average about 6 dB minimum and can often be as great as 10 dB; this is of major importance in critical-hours, nighttime, and pre-sunrise situations where the SIR due to incoming skywave signals can degrade to levels of 12 dB or even worse. From the standard propagation data, at the nominal fringe signal level of 0.5 mV/m (for all Classes of stations except A, defined as 0.1 mV/m), the daytime, groundwave co-channel signals (re **§**73.182) must each be no more than $^{1}/_{20}$ the amplitude (−26 dB) at the stated field-strength contour [or 25µv/m, (5µv/m for A)]. The same corresponding nighttime values of acceptable co-channel interference levels (−26 dB) are specified for Class A, 0.5 mV/m (50% skywave) contours and the 2 mV/m contours for Class B (groundwave); obviously the ***unregulated*** nighttime CCI levels for Class-C (typically 25 mV/m or about 12-14 dB D/U)[9] and Class-D stations are significantly worse. Typical critical-hours and nighttime D/U ratios, even on clear channels, can often be about 12-16 dB, thus providing even greater benefits to synchronized co-channel stations. Allowing for finite ground conductivities, it is evident that an improvement of 6 dB in effective co-channel levels will ***nearly double*** the interference-limited contours of the stations compared with the standard, non-synchronous case (<u>*almost quadrupling the equivalent coverage area*</u>). As will be described later, our lab tests with real broadcast audio demonstrated that for some types of programming (i.e., with good masking properties) the effective improvement can even approach 10 dB, which could nearly triple the interference-limited coverage range! With the beats eliminated, the background audio from the co-channel stations will be clean; often, the so-called "cocktail party" effect will reduce the apparent level of those signals to the listener even further, especially in high-background ambients such as automobiles. The net result of these effects will be universally evident but particularly beneficial to nighttime operations at local Class-C and Class-D stations, whose coverage areas are already acutely curtailed by heavy co-channel skywave interference in both critical and nighttime hours. For these latter classes, the near-quadrupling of equivalent coverage at night should be a major benefit, particularly to listeners in outlying suburban areas.

The principal drawback to the approach is a practical implementation issue **−** ***all stations on the channel in question (at least those with signals above the noise floor at the receiver) must be closely frequency-locked to a common precise reference as just described, or the beats will not be eliminated. It is therefore incumbent on the Commission to mandate the wide-area synchronization requirement for all AM stations as soon as practicable.*** In our view, local *and* wide-area AM transmitter synchronization is (and at very low cost) the only technology that, when adopted, will <u>immediately</u> benefit *all* stations, *all* frequencies, and *all* receivers, both day *and* night.

CONCLUSIONS

As we stated in response to the original 13-249 NPRM on AM Revitalization over three years ago, AM radio is a longstanding American institution, a source of unique voices, and one that we can ill afford to abandon, particularly in light of its unique groundwave and nighttime skywave propagation characteristics and tremendous reach, especially in times of local, regional, and even national emergencies**.** We believe that AM radio stations can be relied upon to provide needed service well into the future, but the Commission must take several bold steps in the very near future to preserve AM radio for future generations of Americans. KTL believes that the suggested actions can be undertaken rapidly to encourage a general revitalization of the AM radio service, and we strongly encourage the Commission to take them now. We reiterate our agreement in principle with most of the Comments already offered by others in the consulting engineering community, though with some alternative suggestions. The rapid adoption by the Commission of permanent licensing for AM Synchronous Boosters, both as fill-in and contour-expanding facilities, is both cost-effective, a more efficient use of the spectrum, and is certainly long overdue.

Our general proposals are driven by our overriding view that to save and revitalize the AM band ***for broadcasters and the public***, the Commission must move rapidly and forcefully to: **(1)** enforce Part 15 and 18 Unintentional Radiator rules on Utilities and others; **(2)** enforce Part 15 regulations on non-compliant imported electronics via actions against their domestic vendors; and **(3)** further mandate major improvements in AM receiver performance, especially to achieve near-parity with FM. Also included in our earlier proposals to improve AM reception are the simplified adoption of synchronous booster stations to augment existing AM station coverage and the mandate of wide-area GPS-based synchronization to significantly reduce co-channel interference via the elimination of carrier beats. Without these high-level actions, most of the other suggestions for improving AM service as offered by our firm and other Commenters will likely become moot unless the listening public is incentivized to return to the band, via the rapid establishment of noticeably better audio and reception conditions throughout the U.S. and its possessions.

Respectfully Submitted, December 29, 2016

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